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AN INVESTIGATION OF ATMOSPHERIC DYNAMICS AND MINOR ATMOSPHERIC SPECIES UNDER QUIET AND PERTURBED CONDITIONS

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A program to perform research combining lidar observations and quantitative modeling of dynamic phenomena and minor species distributions in both the naturally occurring and anthropically perturbed atmosphere. Emphasis on investigation of the environmental effects of the chemical by-products of rocket engine combustion in the stratosphere and the effects of rf ionospheric heaters on the dynamics and minor species distributions in the mesosphere and lower thermosphere.

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1. PROGRAM OBJECTIVES

The objective of this three year program is to perform research combining lidar observations and quantitative modeling of dynamic phenomena and minor species distributions in both the naturally occurring and anthropically perturbed atmosphere. We will investigate the environmental effects of the chemical by-products of rocket engine combustion in the stratosphere and also measure the effects of rf ionospheric heaters on the dynamics and minor species distributions in the mesosphere and lower thermosphere.

The research will include characterization of the environment around space launch activities. In particular, stratospheric ozone density perturbations and chlorine compound densities will be measured with a scanning differential absorption lidar (DIAL). We intend to reconcile lidar data collected from space launch activities with current models of the rocket environment. The purpose of this is verify the applicability of specific theoretical projections and to provide data on which to base model refinements. We plan to perform research utilizing a lidar for measurements of mesospheric densities of N_2^+, Ca^+, K and Fe and to apply the existing lidar capabilities to measure temperature and density profiles of the stratosphere and mesosphere to study middle atmospheric dynamics in support of space launch and ionospheric heating activities.

The first year of the program included preparation and initial field test of the system for measurement of the environment near space launch activities. Methods to be used for data analysis were evaluated. During the second year of the program research will be performed at a number of space launch activities and effects of those activities on the environment will be measured. Effects on ozone densities will be determined. Comparison with model predictions will be made. Initial measurements near the HAARP ionospheric heater is planned. During the third year evaluation of the effects of space launch activities will be continued and conclusions will be made. Effects of ionospheric heating will continue to be evaluated.

2. FIRST QUARTER PROGRESS

During this period work progressed in preparation for measurement of ozone depletion in the vicinity of a TITAN IV launch plume. The goal was to be ready on site at Cape Canaveral for a launch the evening of November 1, 1995. Prior to shipment of the trailer in mid October work was completed on the optical system and the pointing system for the trailer DIAL lidar. Measurements of stratospheric ozone were made at Hanscom AFB simultaneous with the launch of balloon-borne ozonesondes. This was done to verify operation of the DIAL lidar against the well accepted ECC ozonesonde instruments which were obtained from EN-SCI Corp. of Boulder, CO.

Upgrades and new features were added to SONIX64.C, the data acquisition program used to control the (Sonix, Inc.) analog to digital converter computer boards. This includes the ability to change quickly between sets of board/display parameters conducive to lidar alignment and those conducive to data acquisition from the atmosphere.

We studied, identified, and mitigated artifacts that appeared in the data which originated in the data acquisition system. This included a non-random deviation (from horizontal) of the baseline which worsened as the number of shots averaged over increased. This was mitigated when the ADC board is used in pretrigger sample mode.

A program was written to aid in tracking the plume with the lidar. The program displays, in realtime, the current time, the time since launch, the elevation and azimuth angles of the lidar beam with respect to both a local scanner coordinate system and a trailer coordinate system, and the predicted plume location (at a chosen altitude) in both of these coordinate system. The predicted plume location is determined with another program and is based on the most recent wind information. The program also writes to disk the scanner elevation and azimuth angles corresponding to each data file.

3. SECOND QUARTER PROGRESS

Early in this quarter the trailer was packed and transported to Cape Canaveral Air Station (CCAS), Florida, via flatbed truck. It was sited near launch pad SLC 34 approximately 16000 ft from the Titan launch pad and oriented to give optimum view of the plume, given the projected wind patterns and the allowed field-of-view of the scanner assembly due to the physical limitations of the hatches.

Arrangements were made with CCAS personnel to connect the lidar trailer to power and phone services for voice/fax/data. The ozone DIAL system was reassembled, inspected for damage in shipment, and tested for local electronics noise variances. One of the SONIX64 boards for the data acquisition system was found to have a faulty data channel and it was removed for shipment back to PhotoMetrics for repair. As the launch was scheduled for the nighttime, the data was to be taken solely with the photon counting system; the analog data acquisition system would be used only to assist in the plume tracking, so the faulty SONIX64 board was not a concern. Various safety issues concerning the laser field of view, access to the trailer site, and posting of appropriate warning signs were addressed. Protocol was established with the CCAS aeronautics control officers for voice communications of laser status and look angle, and establishment of a local no-fly zone during laser operations.

The TITAN IV launch (K-21) lifted from the pad at 12:15 am on November 6, 1995. The plume was acquired successfully from predictive wind models and various segments of the plume were tracked for a period of nearly 4 hours. It was found that the predictive subroutine of the program used to assist in plume tracking was in error, but it did not prove a serious difficulty for this mission. Afterwards the programming error was corrected.

Upon completion of the experiment, optical damage was discovered on the windows of the harmonic crystal housings and on the tripler itself in the YAG laser. Subsequently, the windows were removed and brought back to PhotoMetrics for repair. Damage was also noted on the wavelength separation optics of the YAG laser, but the damage was minimal and the system could be realigned to avoid the damaged portions, so they were not removed. The trailer was made as weather-rugged as possible and all systems shut down before departure.

4. THIRD QUARTER PROGRESS

During this quarter successful measurements on the plumes of the STS—76 shuttle and K-16 Titan IV launches were performed.

For STS-76, the system was disassembled and packed for rotation of the trailer. Rotations was necessary due to the limited field of view of the scanner caused by the physical limitations of the hatches, and the location of the trailer with respect to the shuttle launch pad and launch trajectory. Two cranes were used. It was found that the motion of the trailer was such that only minimal packing of the system would be necessary if both cranes continued to be used for rotating the trailer in the future.

The system was reassembled and tested. The harmonic crystals from the YAG which had been re-coated were reinstalled in the laser system. YAG performance was down considerably and it was discovered that one of the flashlamp capacitor banks was not firing. The problem was found to be a faulty fuse holder and it was repaired. The failed SONIX64 board had been repaired and it was reinstalled in the analog data acquisition system.

The shuttle lifted off at 3:13 am on March 22, 1996. Segments of the plume were acquired and tracked for a period of almost 4 hours. Towards the end of the launch, as dawn approached, data acquisition was switched from photon counting to analog. It was found that the RC time response of the analog system was slow and that this had a tendency to smear out the features in the data.

Damage to the wavelength separation optics was noted to be worsening, but still not severe enough to warrant replacement. The YAG laser was further noted to be mistriggering occasionally for unknown reasons, possibly related to the power unit or one of the capacitor banks. The trailer was weatherized and shut down before departure.

For K-16, the trailer was again rotated to allow for a field-of-view appropriate to the TITAN IV launch vector and predicted wind values. All data preamplifiers, photon counting and analog, were installed in a heavily shielded computer case to reduce RFI. The arrangement, furthermore, allowed for rapid conversion from photon counting to analog data acquisition mode and back again in preparation for the evening launch time scheduled for K-16. The RC time constant of the analog system was adjusted for faster response.

An extra power unit and capacitor bank were brought to the site for possible replacement should the repair of the YAG laser mistriggering require it. The YAG mistriggering was found to be a combination of three problems. Firstly, the system clock contained a faulty buffer amplifier, which would occasionally fail to trigger the YAG laser. This was replaced. Secondly, the relays which control power flow to the motors on the scan mirror were found to interfere with the YAG triggering when they opened or closed. No solution for this has as yet been found, but the problem is minimal. Thirdly, the radios used for communications with the aeronautics control officers for monitoring of the laser status and airspace clearance were found to interfere with the YAG trigger. The radio was further found to interfere with the joystick control of the scan mirror. It was found that when not used in the vicinity of the electronics rack, that neither the YAG laser nor the joystick were effected.

The TITAN IV lifted off at 7:37 PM on April 24,1996. Data acquisition was analog at first, but switched to photon counting after sunset. The sensitivity of the analog system was found to be reduced but adequate, which was to be expected with the new RC time constant of the system. Segments of the plume were monitored for a period of almost 4 hours.

The wavelength separation optics in the YAG laser were determined to be damaged badly enough to require recoating. They were removed and returned to PhotoMetrics. Temperature variation of the harmonic crystals within the YAG laser required frequent adjustment of their mounts for optimum power output. A heater system for the crystals exists within the YAG laser, but it had not been used in some time. It was removed and brought back to PhotoMetrics for testing and any repair necessary. The trailer was weatherized and shut down before departure.

5. FOURTH QUARTER PROGRESS

The oven and oven controller for the THG crystal of the YG581 laser were removed and tested after a burning odor was detected from them shortly after the laser was powered. Inspection of the controller revealed the SCR was discolored, and the associated slow-blow fuse was partially melted, indicating the unit had overheated, but the assembly performed well during testing. The oven and controller were reinstalled in the laser head and have since performed normally. It was concluded that an intermittent short occurred either in the cable or the oven, which did not recur during testing. The cable was replaced, and a spare SCR was been procured

The 355/532 nm 45 deg. HR mirrors used in the YG581 wavelength separation package (WSP) had burned during operation. They were removed and returned to CVI for inspection. Dr. Kim of CVI concluded the coatings weren't the best they could do and scheduled a coating run to replace the damaged optics. The replacements were cemented in mounting rings, installed in the WSP, and have exhibited significantly less degradation than their predecessors for an equivalent number of hours of operation.

Irradiance calculations as a function of local time were performed to estimate the dependence of photochemistry in the plume at times close to sunset, as occurred during the K-16 Titan IV launch. Cursory analysis suggested that irradiance over the dominant absorption bands of chlorine at altitudes where the plume was detected is relatively close (> 50%) to midday values until about 5 minutes before sunset. At 20 km altitude, sunset occurred about 30 minutes after launch. Raw data from the K-16 launch was converted to ASCII format, documented, correlated with look-direction, and uploaded for subsequent processing.

Work was begun on the sodium summed-YAG laser. A program was written to use the DAS40 as a strip chart recorder to monitor the polarization rotation signal while turning power on and off to the oven. The signal was significantly noisier with the oven on than with it off.

We removed, repaired, and replaced the piezo transducer which adjusted the 1.3 μm oscillator cavity length. The piezo had broken at a glued joint and the rear high reflector for the laser fell off with it. The oscillator was realigned and it performed as well as before.

The telescope coupling the seed laser to the 1.3 μm host oscillator was reinstalled and vastly improved seeding was obtained, as evidenced by the Q-switch build-up-time (QSBUT) reductions being several times what was previously obtained without the telescope. Several locations and orientations of the telescope, which simultaneously provided good coupling without focusing the rejected host radiation back into the seeder or turning mirrors, were tested. Best performance was obtained at the original location, with the telescope as close as possible to the host oscillator.

With poor or no seeding, burns from the multimode cavity were uniform, top-hat intensity profiles. With good seeding, as was obtained with the telescope, only a few transverse modes lased, and structure in the far-field intensity profile was obvious. In particular, a persistent binocular-bolt pattern was obtained.

We tested the Ophir power meter to determine the cause of the discrepancy between it and the Scientech meter.